International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

International Journal of Energy Economics and Policy, 2023, 13(5), 407-424.

Regulatory Proposals for the Insertion of Distributed Energy Resources based on a Brazilian Utility Case and International Experiences

Julieta Rico*, Erick Pelegia, Nilton Amado, Welson Bassi, Ildo Sauer

Institute of Energy and Environment, University of São Paulo, São Paulo, Brazil. *Email: julietapuerto@gmail.com

Received: 27 April 2023 **Accepted:** 15 August 2023 **DOI:** https://doi.org/10.32479/ijeep.14575

ABSTRACT

Utilities, policymakers, regulators, free market, utility consumers and prosumers share a common interest in understanding whether benefits associated with such increased of DERs outweigh costs. To dimension and qualify B/C relationship, there are intrinsic variables relative to DERs' technical-economic arrangement and standard mechanisms used for its compensation: NEM, feed-in policies, etc. On the other side, DERs must be adjusted on established regulatory framework, tariff schemes and utility revenue models. In this article, these three ambits are analyzed including a Brazilian southeastern region user's case study connected to MV network with DG measured data. Thus, some guidelines are pointed for the comprehensive implementation of DERs from the perspective of those involved.

Keywords: Distributed Generation in Brazil, Brazilian Prosumers, DG' Benefit/Cost
JEL Classifications: P48; Q42; Q48

1. INTRODUCTION

The growing insertion of Distributed Energy Resources (DERs) creates the necessity of, among other issues, to formulate procedures capable of economically valuing their benefits, to evaluate the impacts on the expansion and operation of networks and changes in the electricity matrix as well as the role of the utilities as buyers of flexibility in local markets. DERs are small or medium-scale resources that can provide services directly to the power system, linked to the distribution network, or close to the final consumer (IRENA, 2019). The DERs include: (i) Distributed generation (DG), (ii) Energy storage, (iii) Electric vehicles (EV) and electrical charging structure, and more recently, (iv) Energy efficiency, and (v) Demand response (DR), (vi) Demand side management (DSM) (EPE, 2018; IRENA, 2019).

Distributed Generation based on solar-photovoltaic (PV-DG) has increased significantly. Only between 2019 and 2021, 167 GW were installed globally, 53% in the commercial/industrial sector and 47% in the residential sector (IEA, 2022). The PV-DG Levelized Cost of Electricity (LCOE) has dropped by 40-70% since 2010 (IEA, 2022). With the results achieved so far and depending on the country, there is an expectation that PV-DG costs will be comparable to current electricity prices.

In Brazil, DG regulatory framework started in 2004 authorizing to contracting DG limited to up to 10% of the utility's market (Brazil, 2004). Subsequently, Brazilian Normative Resolutions N°482/2012 established the Electric Energy Compensation System - SCEE[1] for energy surpluses and N°687/2015, established to use energy surpluses for 60 months (net metering-rolling credit), at the same price as the retail tariff (ANEEL, 2012; ANEEL, 2015). Currently, 99% of installed DG in Brazil are PV-DG facilities (EPE, 2023). Between 2014 and 2021 Generation PV costs in auctions decreased from USD 90/MWh to USD 30/MWh (R$215/MWh to R$160/MWh)[2] (EPE, 2022) and DG installed capacity

1 Abbreviation in Portuguese for Sistema de Compensação de Energia Elétrica
2 Dollar 2021. EPE Data: Reserve Energy Auction/2014 - New Energy Auction A-5/2021

This Journal is licensed under a Creative Commons Attribution 4.0 International License

increased from 5 MW to 17,000 MW between 2012 and 2022 (ANEEL, 2023b).

As the number of DG facilities increases, the discussion for the prosumers has been about DG costs, mainly the Tariff for Use of the Distribution System (TUSD) and the time that it will be subsidized. For those who requested access to the distribution network before and within 1 year after the publication of the new regulatory framework for distributed mini and micro generation MMDG, the DG' exported energy to network has been and will continue to be fully deducted until 2045 (Brazil, 2022). For those with connection requests after January 2023, the TUSD began to be charged at a percentage of 15% since 2023 and will increase progressively until it reaches 100% in 2030 (Brazil, 2022).

For consumers, the current commercial model allows to migrate to the SCEE if their monthly demand is below 500 KW, including low voltage residential ones, however, the same consumers cannot yet be part of the Energy Free Market (ML)[3] (Medeiros, 2022). For the time being, by measure to be implemented on January 1 of 2024, the purchase of electrical energy at ML will be allowed for consumers with individual load <500kW by Ordinance MME N°465/2019.

For utilities, in addition to TUSD payment by prosumers, the questions are focused on massive addition of the micro-generators and the decrease consumption of electrical energy. This dynamic would result in an increase on the regulated market rate, which, in turn, would be lower. Being the smaller market, the costs, in the periodic rate revisions, would be divided by a smaller number of consumers. In this way, the phenomenon called death spiral would affect the utilities (Castañeda et al., 2017).

An initial assessment to establish DG evolution can be guided from the benefits that DG offers. For example, the utility can purchase flexibility services from the local DERs system to solve problems related to voltage regulation, power quality, and congestion of the distribution network, as well as investments deferral of the network (IRENA, 2019). Likewise, DERs can contribute to meeting local demand by reducing system load peaks and participating in DSM programs. However, the prior conditions to the installation of DG such as tariff regulation, procedures for purchasing energy, tariff schemes, mechanisms designed to encourage the prosumer, and mechanisms for regulating the distributor's revenue are those that allow how far those benefits can be achieved.

In this paper, some mechanisms used for the deployment of DG in the national and international landscape are analyzed, as well as the tariff conditions and regulation model in force in Brazil and other countries. This analysis, together to theme specific approach through Brazilian Southeastern Region's user with installed DG allows the elaboration of some recommendations considering the valuation of the benefits/costs from the perspective of the groups involved. The recommendations can contribute to the integral understanding of routes for the exploration of DG benefits, which can be extended to other analyses.

3 Abbreviation in Portuguese for Mercado Livre de Energia where the purchase and sale of energy takes place and, commercial conditions such as supplier, price, amount of contracted energy, period of supply, payment, among others, are trading freely.

2. MATERIALS AND METHODS

DG benefits' measuring is not specific to the Brazilian DERs context. Some initiatives have already been elaborated from the point of view of system operation (Pudjianto et al., 2006) and others from a broader perspective including a regulatory framework (IREC, 2014). In Brazil, a roadmap to acquire and offset the benefits of DG has not yet been defined. An approximation was intended on Resolution N°15/2020 of the National Energy Policy Council – CNPE, which established as an interest of the National Energy Policy, among other guidelines for MMDG: emphasizing guidelines that allow the allocation of network costs considering their benefits (CNPE, 2020). Later, Normative Resolution (NR) N°1009/2022, ANEEL presented some DG benefits to establish bilateral distributed generation contracts (ANEEL, 2022). More comprehensively, ANEEL, through the Regulatory Impact Analysis report (AIR No. 0004/2018), elaborated a guide that identifies the possible DG's benefits and costs (ANEEL, 2018). In this paper, the methodology consists of a qualitative analysis of both national and international DG regulatory framework and a case study of a technical economic arrangement involving dispatchable DG and intermittent sources. These elements contribute to the valuation DG benefits/costs from the perspective of the utilities, prosumer, consumer without DG and planner.

Conventionally, the qualifying of DERs benefits starts by compensating for exported energy, or the liquid measuring energy through Net Metering - NEM. However, the adoption of NEM raises questions about the inequities between the costs for using the network by the prosumer and transmitted to the consumer without DG. This work presents a survey of the application of the NEM, and other forms of compensation in several countries. Additionally, NEM and other measures focused on DG valuation must be adjusted to the structure of a previous regulatory framework that allows the payment of exported energy and the valuation of DG's power contribution into the tariff schemes. Thus, the schemes used in several countries are analyzed under the concept of multipart tariffs, observing the simultaneity between the presence of capacity, energy and/or fixed components, and the use of NEM. Another theme explored are the models used to possible shielding of the concessionary revenue against the insertion of DERs.

In the perspective of harnessing DG benefits the Brazilian experience is approached from the current regulatory framework, mainly the power and energy components into tariff structure. Subsequently, the trajectory of legal framework for MMDG and the adjustments to maintenance of this subsidized market are identified. The evolution of DG's measures is presented considering the point of view of distributors, prosumers, planner, and associations as: Brazilian Association of Electricity Distributors (ABRADEE), Brazilian Association of Energy Traders (ABRACEEL); Brazilian Association of Large Industrial Energy Consumers and Free Consumers (ABRACE) Brazilian Association of Independent Electric Energy Producers (APINE); Brazilian Association of Investors in Energy Self-Production (ABIAPE). As well as involving migration of consumers to the ML versus to DG' compensation system and the impact on the payment of subsidies by the utility consumers.

Data of a feeder named USP-105 of the University of São Paulo campus underground distribution system located in the Southeastern Region of Brazil allows the quantification of some benefits. Thus, energy consumption and demand of the USP network's circuit USP-105 as well as demand tariffs and energy for peak and off-peak periods are used. The avoided energy and capacity costs are calculated according to the installed DG in feeder USP-105: one biogas plant and two solar-photovoltaic plants at the Institute of Energy and Environment (IEE)/USP, as well as one solar photovoltaic plant, and energy efficiency measures at the University Hospital. All the data used are direct measurements, either on the university's medium voltage network on feeder 105, or on the already installed DG. In the case of the biogas plant, measurements were taken during the implementation process and some projections were made. Finally, the analysis of the participation of utilities, prosumers, and consumer without DG is quantified with figures of merit such as payback, Net Present Value (NPV), and Investment Return Rate (IRR). Additionally, biogas plant implementation has been used to evaluate a wider range of benefits involving other sectors such as environmental and agricultural.

3. THE DISTRIBUTED GENERATION AND THE CONDITIONS FOR ITS INSERTION: INTERNATIONAL OUTLOOK

In the international landscape, some elements have been identified to facilitate the implementation of DG and integrate it in a structured way. The alignment between them seeks a balance between the utilities' revenue and its allocation among distribution network users through tariffs. The common elements found are: (i) a regulation that produces adequate economic signals for the Distribution Network Operators, capable of taking into account the additional costs arising from the integration of DG and remunerating them accordingly, (ii) fair tariffs for all users, (iii) net energy measurement: Net-Metering (NEM), (iv) incentive mechanisms to value the hosting capacity and the value/location signal (v) hourly or intra-hourly electricity prices (Picciariello et al., 2014; Picciariello et al., 2015; Fine et al., 2020). In other words, a structure goes to meeting the interests of multiple prosumers without generating long-term imbalances in other consumers and the utilities. Next, each of these items will be discussed.

Regarding proper regulation of DERs, the Decoupling is a mechanism facing the loss of the utilities' revenue. This mechanism guides the shielding of the utility against market risk based on the segregation of revenue from the volume of monetized resources. The application of Decoupling breaks the link between the amount of energy that the utility provides, and the revenues collected (RAP, 2016). Without decoupling, the regulator calculates the required revenue, estimates the level of sales, and sets the tariff on this ratio (RAP, 2016). With decoupling, a small credit or surcharge is implemented, usually per kWh, to return the surplus or make up for the deficiency (Linvill et al., 2013). Expression 1 explains the Decoupling procedure according to RAP (2016):

$$\text{Revenue Requirement} = (\text{Expenses} + \text{Return} + \text{Taxes})_{\text{without decoupling}} \quad (1)$$
$$\text{Rate} = \text{Revenue Requirement}/\text{Units Sold}_{\text{without decoupling}}$$
$$\text{Profit Actual} = (\text{Revenues} - \text{Expenses} - \text{Taxes})_{\text{without decoupling}}$$
$$\text{Revenues Actual} = \text{Units Sold Actual X Price}_{\text{without decoupling}}$$
$$\text{Revenues Actual} = \text{Revenues Allowed}_{\text{without decoupling}}$$
$$\text{Price Post Rate Case} = \text{Revenues Allowed} \div \text{Units Sold Actual}_{\text{without decoupling}}$$

Regarding fair tariffs, these are defined within regulatory models such as the price cap (Brazil, Netherlands, Austria), revenue cap (Germany, France, Great Britain, Sweden, Norway), or the rate of return (Simone and Borges, 2019). A revenue cap differs from a price cap model in that the regulator places an upper limit on the regulated utilities' revenues rather than an index of prices (Campbell, 2015). Price cap links utility profits to the amount of electricity sold while revenue cap separates sales from revenues (Dubash, 2004). Although the decoupling shields the utility against market risk, with this measure, tariff adjustments become more frequent (Câmara, 2020). Although the decoupling consideration is separate from the rate design but, the prospect of reduced revenue may require a tariff adjustment to ensure that the necessary network services are financed (Linvill et al., 2013). The tariff design concerns play a more prominent role as DERs increase. The tariff schemes include one or more components where DG can be, more or less, valued. Tariffs can be classified as follows:

I. Multipart tariffs, which combine two or more of the components: Volumetric ($/kWh) proportional to the energy consumed by each customer charged at a rate which may fluctuate by time of the day within the considered period (Picciariello et al., 2015); fixed charged ($/period) or invariable rate intended to cover infrastructure costs, regardless of customer consumption generally, it can be based on DG system capacity, inverter capacity or breaker size (Picciariello et al., 2015; Lu and Waddams, 2018; Câmara, 2020); Capacity (R$/kW) that is collected based on the maximum power used during a specific period, regardless of the duration or frequency of that consumption level (Lu and Waddams, 2018; Câmara, 2020).
II. Time of use (ToU) tariffs: middle term between volumetric tariffs and real-time tariffs (Ansarin et al., 2020). They have different prices for volumetric consumption at different times of the day, week, or year and can be static, where prices and periods are predefined based on historical data; and dynamic, where prices can vary hourly or dividing the day into periods, offering a value for each period, or by demand or critical consumption (critical peak pricing) (Oliveira, 2018).
III. Locational tariffs: established according to the connection point and power injection in the electrical system. These may be an option for pricing DG (Oliveira, 2018).
IV. Hourly-seasonal: imposed in locations whose utilities have significant seasonal cost differences.

The volumetric, fixed, and/or capacity components are used within the multipart tariff scheme. Capacity charges tend to provide more stable and predictable distribution revenues, while network usage and load expectation are the basis for network planning and sizing and those parameters are related to the evolution of number of consumers and capacity (Alba and O'Briain, 2021). In this sense, capacity is a good approximation for investments and therefore network costs.

In the multipart tariff, the capacity component may be intended to cover the fixed costs of the infrastructure shared with other customers in proportion to the capacity each need (Picciariello et al., 2015). It can also be charged to recover fixed network costs while sending adequate demand response signals (Ansarin et al., 2020). The capacity structure can be (i) a flat charge for a pre-defined capacity like as set out for medium and high voltage users in Brazil; or like in Uruguay with the simple residential tariffs and general simple tariffs and hourly-seasonal (Picciariello et al., 2015; UTE, 2022; ENSEK, 2021; Câmara, 2022). In Netherlands, users with a load of <2.4 kW have a capacity-only tariff and generally a flat charge (Alba and O'Briain, 2021) (ii) a variable charge for each capacity level, as in the case of Portugal, Italy, Mexico (Picciariello et al., 2015; ARERA, 2018; ERSE, 2022; CFE, 2022) (iii) Time of use capacity charge, characterized by a price per kW which depends on the time of use like in Spain, France, and Chile differentiated for peak and off-peak periods or based on peak demand like residential users' tariffs in Sweden and Finland (Picciariello et al., 2015; OCU, 2021; CGE, 2022; Alba and O'Briain, 2021). Table 1 shows the use or not of the capacity component in some countries.

Regarding DERs' compensation mechanisms, consumers with the ability to produce electricity and inject it into the grid may be entitled to receive some compensation. The most common are: (i) feed-in policies (ii) quota policies (iii) auctions and bids (iv) Net Metering (NEM), and other self-consumption policies such as rooftop programs (REN21, 2022; Sioshansi, 2016). Net Metring is the most used mechanism. However more accurate values of DERs make some criticisms about net energy measurement (NEM) to be directed. Among others: with NEM, onwards the tariff tends to increase to cover the network costs as registered consumption decreases (Gautier et al., 2017); the adoption of NEM together with the application of volumetric tariffs facilitates the occurrence of a cross-subsidy from customers without DG to customers with DG (Comello and Reichelstein, 2017, Geffert and Strunk, 2017, Picciariello et al., 2014).

Better targeting of NEM suggests the application of volumetric tariffs separately for producers and consumers and that network cost allocation is based on a cost-causality basis (Picciariello et al., 2014). It is also suggested that the application of a rate close to the LCOE and lower than the retail tariff for exported energy and paid separately from consumption, creating a perspective for the adoption of a net billing/net purchasing (Comello and Reichelstein, 2017, Geffert and Strunk, 2017). Usually, in the net billing there are two meters: a traditional one to measure electricity drawn from the grid and an export meter to measure the power supply to the grid The energy exported to the grid is sold to the distribution utility, for example, as the cost avoided by grid upgrades or as a fraction of the wholesale market price. Table 1 shows the adoption of Net Metering and other mechanisms to compensate for surplus energy and the volumetric, fixed, and capacity components used in some countries within the multipart tariff scheme.

Regarding hosting capacity and locational value, the maximum capacity to be connected can anticipate the positive or negative possible impacts of DG systems on distribution networks. The power of DG, or any DER that can be connected to an electrical distribution network without affecting the quality of the energy supplied before improvements or reinforcements need to be carried out in the electrical infrastructure is called Hosting Capacity (HC) (Hall et al., 2018, McAlister et al., 2018). However, CH may not be enough for consumers to want to invest in MMDG. Assigning a value to the benefit of distributed generators in a specific location or Location Value (LV) is necessary. LV indicates where DERs can defer upgrades, a demand reduction value (DRV), and a location system decongestion value (LSRV) (McAlister et al., 2018).

In United States were implemented experiences recently towards Value Hosting Capacity and Locational Value to replace the Net Metering scheme (Hall et al., 2018) (Table 1). In New York, the Value of Distributed Energy Resources (VDER) was created to reflect the benefits and costs of DG-PV to provide a more accurate billing rate for solar energy surpluses and to avoid transferring costs to homeowners without DG. Under the VDER, excess solar energy is purchased by the Value Stack Tariff, which considers wholesale energy prices, how much the project decreases grid demand, how much the project reduces the need for future utility upgrades, and environmental benefits in the network and society by installing solar energy (Hall et al., 2018).

In short, DG insertion can be affected by mechanisms that compensate the avoided net energy and capacity; form and terms in which the tariff scheme is structured; the presence or absence of decoupling for utilities' revenue regulation and prospects of determining the DG locational value. In Brazil, some of these elements have been formulated for the implementation of DG, but the mechanism used to compensate exported energy is net metering. The evolution of DG takes place within the price cap tariff model and a predominantly volumetric tariff scheme. Next, the implementation and regulatory context of DG in Brazil is explained.

4. TARIFF SCHEME IN BRAZIL AND DISTRIBUTED GENERATION'S REGULATORY FRAMEWORK

In Brazil, the current tariff scheme brings together volumetric tariffs based on energy consumption per period, applied in the B group (low voltage) including B1 or residential subgroup, in the white[4] and conventional[5] modalities, as well as the binomial tariffs, applied on group A (high and medium voltage) in blue[6] and green[7] modalities. Binomial tariffs separately have a fixed monthly

4 Volumetric tariff with the value distinction at three tariff stations: peak, intermediate and off-peak.

5 Volumetric without tariff periods

6 It is mandatory for consumer units A1, A2 and A3, and optional for other subgroups A. There are tariffs for power demand and energy consumption for peak and off-peak hours.

7 Available for subgroups A3a, A4, and AS. It has a single demand tariff and different energy consumption tariffs for peak and off-peak hour.

Table 1: Compensation mechanisms for DG and tariff schemes in some countries

Country	Compensation mechanism	Tariffs components		
		Fixed	Volumetric	Capacity
Belgium	Net-Metering, Tradable green certificates. Fixed tariff based on the power (kWp) of the inverter.	X	X	X
France	Feed-in-tariff, Premium Tariff, Tax Reduction		X	X
Germany	Guaranteed feed-in tariff for 20 years, a connection obligation and a preferential feed-in	X	X	
Italy	Net-Metering, Premium Tariff, tax reduction	X	X	X
Netherlands	Net-Metering, Premium Tariff, scheme covering 30% of the costs for buying and installing batteries. The storage's viability for surplus energy is projected for 2023.	X		X
Portugal	Net Billing. Self-consumption regime with remuneration for surplus energy to 90% of the market price.		X	X
Spain	Net Billing with no rolling credit. Sell of the surplus through an agent in the market or PPA (Power Purchase Agreements).		X	X
United Kingdom	Feed-in-tariff: applied to guarantee a 5% rate of return on investments in DG, for well located projects. Tariff regression system, which tracks the cost trajectory of DG technology.	X	X	
Denmark	Pioneered implementing Net Metering with electricity tax exemption in 1999. Currently, the only advantage for new PV prosumers under the Danish Net Metering scheme is the compensation of self-generation and consumption within an hourly basis.	X	X	
Norway	Advanced Metering and Management System: hourly meter readings have been installed in all households. FIT, Swedish-Norwegian RECS, Enova Subsidies, self consumption, Green Certificates.	X	X	
Sweden	Feed-in premiums, Capital subsidies, Renewable Energy Certificates (RECs), Guarantees of origin, tax credit for micro-producers of renewable energy, capital subsidy for storage of self-produced energy.	X		X
Finland	Building integrated photovoltaic support measures, hourly-based-net billing for individual customers.	X		X
Canada	Net-Metering since 2016, 12 months rolling credit. Residential customers: (ON) ToU: off-peak, mid-peak other provinces: tiered or flat. Small-Medium-Large-Power Customers: ′/kWh according to MW installed and load factor.	X	X	
Chile	Net-Metering/Billing - Law 20.571/2012	X	X	X
México	Net-Metering - is computed by a digital meter with the ability of measuring the power input and output (bidirectional meter). 12 months rolling credit	X	X	
Uruguay	Net-Metering, Decree N° 173/2010	X	X	X
United States	Net metering began with utilities in Idaho in 1980 and Arizona in 1981. Thirty-eight states, Washington, D.C., and four territories offer net metering, and two additional states—Idaho and Texas—have voluntarily adopted net metering programs. Seven states—Arizona, Georgia, Hawaii, Indiana, Nevada, Maine, and Mississippi—have statewide distributed generation compensation rules other than net metering. CALIFORNIA NEM 3.0: towards Net Billing requires customers to switch to specific Time of Use billing plans, reduce compensation for energy excess, and measure energy exports in real-time, as opposed to the current practice of reconciling exports and imports on an hourly basis. NEW YORK: NEM, was established in 1997, but to mitigate some of the cost-related issues caused by net metering, the state's PSC devised - the VDER	Depends on the ISO. – 14% of all US utilities offer a residential TOU rate. In CAISO: Time-Of-Use plans, TOU 4-9PM and 5-8PM plans offer low prices when solar power is contributing to the power grid. TOU-D-PRIME: a special rate for plug-in hybrid owners, residential batteries, or electric heat pump systems. NYISO: Monthly Zonal Base Rate Components for RNY Customers include: (1) Market Energy Component; (2) Capacity Component (for all Zones); and (3) Bad Debt Risk Component.		

Source: Hydroquebec, 2022; UTE, 2022; SCE, 2022; Faruqui et al., 2019; Energyhub, 2021; Martín et al., 2021; Campos et al., 2020; SWECO, 2019; Hall et al., 2018; Hinz, 2018; McAlister et al., 2018; NYPA, 2017; NCSL, 2017, RECS: Renewable energy certificates, PSC: Public service commission, VDER: Value of distributed energy resources, FIT: Feed-in-tariffs, ISO: Independent system operator

capacity variable and volumetric energy consumption variable. For both residential and medium-high voltage subgroups, the TUSD components relating to charges and losses and the TUSD FIO A and TUSD FIO B are measured in BRL/MWh. TUSD FIO A includes expenses related to both maintenance and operation of transmission lines. TUSD FIO B comprises operating costs, amortization, and remuneration of capital invested by the Utility. However, there is also a tariff component TUSD FIO A and FIO B for medium and high voltage in BRL/kW. The components for group B1 in conventional mode and group A4 green are shown in Figure 1.

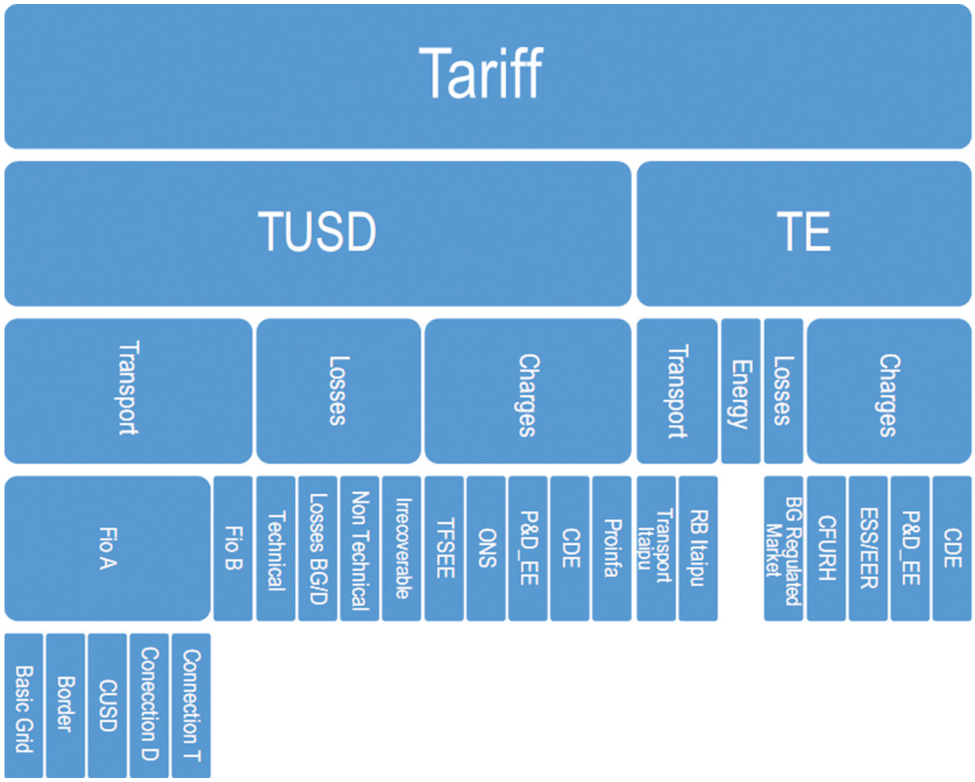
Both components, energy and TUSD, are re-calculated and validated by ANEEL in the Periodic Tariff Review (RTP)[8] every 4 years. The model that underlies the RTP is the price cap that establishes maximum tariffs to cover distribution costs. In the reform of the 90's, the price cap model was implemented, which until today determines a ceiling price in the electricity tariff for a regulatory period (ANEEL, 2019a, Simone and Borges, 2019). Currently, the procedures make up: a first step, considering the productivity gains

8 Abbreviation in Portuguese for Revisão Tarifária Periódica.

of each concessionaire, operating costs are repositioned according to their evolution vis a vis the number of consumers and network extension. Subsequently, service benchmarks are defined based on verifying the best performances among other companies (Aguiar and Marinho, 2019, Castro et al., 2020).

In the RTP process, the TUSD FIO B is called portion B. The value of this component is not uniform and is validated and calculated on RTP for each utility. An average value close to 25% of the total tariff (before taxes) is usually reached. Basically, TUSD FIO B comprises operating costs, amortization, and remuneration

Figure 1: Tariff components for residential and medium voltage subgroups



Source: adapted from ANEEL, 2018a

Table 2: Composition of A and B portions for the Periodic Tariff Review of 2019 - Enel utility

Charges	18.7%	USD 732.734.318
Electrical energy services inspection fee – TFSEE	0.1%	USD 4.737.918
Energy development account (CDE)	13.1%	USD 512.660.323
Contribution on system service charges (ESS) and reserve energy (EER)	2.1%	USD 81.027.620
Incentive program for alternative sources of electric energy PROINFA	2.5%	USD 97.019.329
Research and development and energy efficiency (R and D and EE)	0.9%	USD 37.135.433
Contribution to the national electric system operator	0.0038%	USD 153.697
Transport: It recovers the transmission costs related to the transport of electricity from Itaipu. Basic grids's transmission systems usage (230 kV and above), and other shared transmission facilities, and distribution systems usage of other distributors	11.4%	USD 446.988.854
Basic grid	6.8%	USD 271.918.002
Border basic grid	1.7%	USD 66.102.348
Basic grid ONS (A2)	0.0034%	USD 135.369
TUST Itaipu	0.9%	USD 33.446.043
Itaipu Transport	1.3%	USD 51.500.470
Transmission connection agreement (CCT)	0.6%	USD 21.602.840
Distribution connection agreement (CUSD)	0.1%	USD 2.283.783
Energy	31%	USD 1.541.895.968
Losses	14%	USD 254.718.864
Portion A (Charges+Transport+Energy+Losses)	75%	USD 2.976.338.005
Administration, operation and maintenance costs (CAOM)	12.5%	USD 493.698.765
Annual cost of assets (CAA)	12.4%	USD 487.773.635
Portion B (adjusted)	25%	USD 983.960.929
Required revenue		USD 3.960.298.934
Verified revenue		USD 3.845.983.516

Source: ANEEL, 2019

of capital invested by distributors. In RTP, the portion A also is validated. It portion is relative to the purchase of energy, charges, transport, and losses. Both portions, A and B, later define the values of the electricity tariff components shown in Figure 1. The A and B portion values and its composition for the RTP/2019 of Enel utility are shown in Table 2. The remuneration of the investments necessary for the provision of distribution services, or portion B, plus the variables of portion A define the Required Revenue (RR). The utility's revenue of the period prior to RTP corresponds to the Verified Revenue (RV). The relationship between both defines Tariff Repositioning (Expression 2) (ANEEL, 2019).

$$RT = \left(\frac{RR}{VR} - 1 \right) \times 100 \tag{2}$$

RT: Tariff Repositioning (%);
RR: Required Revenue;
RV: Verified Revenue.

To attend the energy purchasing there is the Regulated and Free Contracting Environment, RCE and FCE respectively. In the RCE, distribution agents purchase electricity through public auctions promoted by the National Electric Energy Agency (ANEEL) and operated by the Electric Energy Trading Chamber (CCEE), to serve their market (utility consumers). Free consumers, on the other hand, buy energy directly from generators or traders, through bilateral contracts with freely negotiated conditions, such as price, volume, etc. Each free consumer pays by the distribution network use to local concessionaire, and by energy to generators and traders with a negotiated contract price.

The current commercial model allows to consumers with monthly demand below 500 kW, including low voltage residential ones, to migrate to the distributed generation market (Medeiros, 2022). However, the same consumers cannot yet be part of the free market. The free market requires consumers to have a contracted demand of at least 500 kW and belonging to Group A, or a minimum contracted demand of 1500 kW and belonging to any group of consumers. In Brazil there are currently 89 million energy consuming units. The free contracting environment, despite having only 0.03% of consumers, became responsible for 38% of the electricity consumed in the country (Canal Energia, 2022). The opening of the free energy market has been gradually evolving. According to Ordinance MME N°465/2019, the current legal limit should be reduced from 2024 and consumers with a load equal to or >500kW and any voltage level will be able to participate (MME, 2019).

One concern for ABRADEE refers to the added costs to the Energy Development Account (CDE) that an opening of the free market could cause to utility consumers (ABRADEE, 2022). ABRACEEL, on the other hand, mentions that the subsidies caused, and deducted from the CDE, by migration to the free market will be lower than migration via the distributed generation market (Medeiros, 2022). For prosumers connected before and 1 year after of publication of the MMDG, regulatory framework subsidies also will be funded by CDE (Brazil, 2022). Currently the Brazilian DG market reaches 17 GW installed and 1,655,819 consumer units (ANEEL, 2023b).

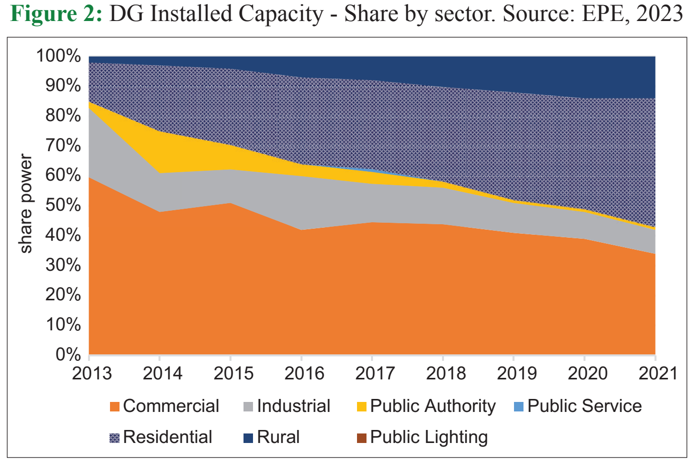
4.1. Distributed Generation in Brazil

The Brazilian regulatory framework regarding DG started since 2004 allowing to distributors meeting 10% of their load by contracting DG into conditions implemented through Federal Decree N°5163/2004 (Brazil, 2004). So far, no utility has signed an energy and/or power purchase agreement from DG. Posteriorly, through ANEEL' Normative Resolution REN N°482/2012 has been established the conditions for access to distributed micro and mini generation (MMDG) (ANEEL, 2012). This normative created the Electric Energy Compensation System - SCEE, where energy surpluses are credited in kWh to be used at another tariff station (white tariff) or in the bill for subsequent months (conventional tariff) (ANEEL, 2012). That mechanism is classified as a Net Metering–rolling credit. Later, REN N°687/2015 established that the remaining energy credits generated must be valid for 60 months (ANEEL, 2015). Thus, every month bill considers the energy consumed, deducting the energy injected and any energy credit accumulated in previous billing cycles on all the tariff components in BRL$/MWh.

The Brazilian regulation for self-generation tends to lead savings in energy charges, but not in capacity charges. The tariff for residential users is 100% volumetric, composed only of energy -based charges. For the medium-high voltage subgroups, there are separate capacity and energy components. However, the installed power is based on the inverter's power, and it cannot be greater than the contracted demand. The minimum payment is charged according to contracted demand. Thus, despite DG, the installed capacity does not contribute to reducing demand payment, while the current payment conditions for contracted demand are not modified. Currently, the most significant number of total PV-DG connections correspond to the residential sector: 3,870 MW installed (43%)[9] and the other sectors add up to 5,130 MW installed. Figure 2 shows the participation by sector into the total installed DG.

9 EPE, 2023

Figure 2: DG Installed Capacity - Share by sector. Source: EPE, 2023



Source: EPE, 2023

In 2019, a DG compensation system was proposed but there was a mismatch between the expectation generated in previous public (Consultation No. 25) and the published proposal (Codeiro, 2019; ANEEL, 2019b). A new Law Project (N°5829/2019), was presented with the support of the photovoltaic solar industry, seeking to maintain the Electric Energy Compensation System (SCEE) for 26 years. This Law Project was implemented as Law N°14300 of January 2022, which established the Distributed Micro and Mini Generation (MMDG) legal framework (Brazil, 2022). The new framework has not had change the Net Metering-rolling credit as compensation mechanism but set up period of application of the measures in force until 2045.. For old prosumers and those connected up to 1 year after law' publication, the compensation for all volumetric tariff components (BRL/MWh) will continue until 2045 (Brazil, 2022). For new facilities, a transition rule will be applied for TUSD FIO B payment, over a period of 6 years until 2030 (Brazil, 2022).

So far, DG's subsidies for old connections have been implicit in the bill paid by utility consumers. However, MMDG regulatory framework determines that part of DG costs will now be covered by the Energy Development Account (CDE) through a specific CDE-DG quota. The quota will be part of the energy tariff charges and will be paid by the utilities that serve regulated users (ANEEL, 2023). In 2023 subsidies to DG add up US$1.04 billion (BRL 5.2 billion) which US$0.25 billion (BRL 1.4 billion) will be borne by the CDE budget for 2023, while US$0.76 billion (BRL 3.8 billion) will remain implicit in the account of regulated consumers (ANEEL, 2023a).

Another effect of the publication of Law 14300/2022 was the addition of 780,000 MMDG connections, equivalent to 7.6 GW of installed power (ANEEL, 2023b). About 47% of the total connections and 44% of the installed power of the entire history recorded since 2009 occurred after the publication of that Law (ANEEL, 2023b). Between 2012 and 2022, 17 GW have been installed (Figure 3). Despite the increase in installations, there is still a Law Project - N°2703/2022-which proposes to extend the deadline for granting TUSD subsidies for installations with a request for connection until June 2023. However, Law N°14300/2022 already provides: a full subsidy until 2045 for MMDG existing or with connection request to the utility until January 6, 2023 (Brazil, 2022). As well as declining subsidy until 2030 for generators that request connection between the 13th and 18th month after the publication of the Law, that is, between February-July 2023 (Brazil, 2022).

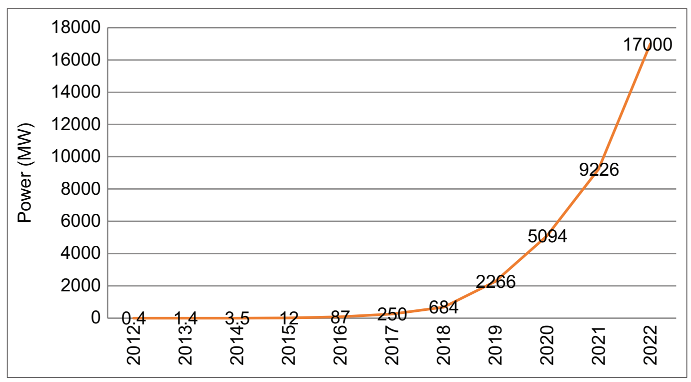
On the benefit side, CNPE Resolution N°15/2020 established of interest of the National Energy Policy, the formulation, and implementation of public policies aimed at MMDG, emphasizing guidelines that allow the allocation of network costs considering their benefits (CNPE, 2020). Later, Decree N°5163/2004 has been enlarged with NR N°1009/2022 establishing the DG contracting through a Distributed Generation Contract – DGC (ANEEL, 2022). The DGC must meet at least one of the following objectives: improving values and indicators of energy quality phenomena: power factor, harmonics, voltage unbalance, voltage fluctuation or frequency variation; the reduction of technical losses; the reduction in the loading of feeders and substations; improvement of distribution service continuity indicators; and the improvement in the voltage profile of feeders (ANEEL, 2022).

Additionally, there are needs to be a better match between the utility's peak hours and the most significant solar photovoltaic generation period. Generally, peak hours for concessionaires comprise the period between 5:30 pm and 21:00 pm, and photovoltaic solar DG has its peak generation from 12:00 pm to 3:00 pm. For Enel – São Paulo utility the peak period is from 5:30 p.m. to 20:30 p.m. For a residential prosumer with a white tariff, the most considerable discount would be applied when the panels are no more producing, and storage systems are needed to use DG. Likewise, in the medium and high voltage groups, the highest demands for capacity and energy consumption are aligned with the DG-PV curve but not with the commercial peak. It should be noted that the peak demand is shifting to the early afternoon, especially in the summer period when the highest load demand occurs (Figure 4).

4.1.1. Viewpoints

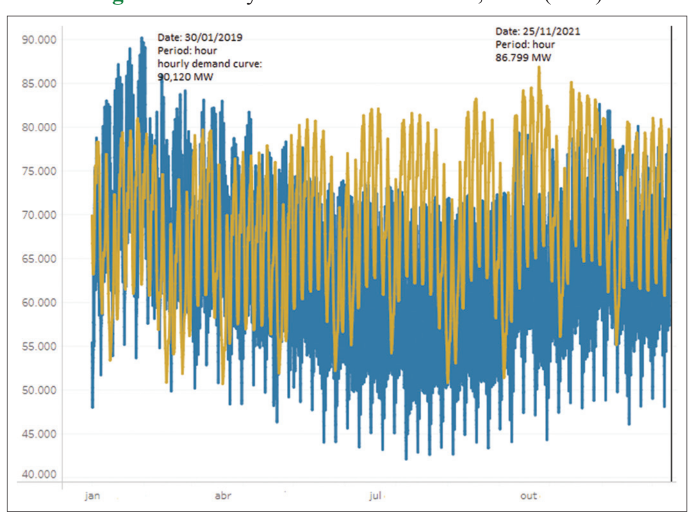
Brazilian Association of Large Industrial Energy Consumers and Free Consumers (ABRACE) pointed out that the credit granted to the prosumer distorts the payment related to fixed costs, reducing them, and displacing this value to other consumers, where the

Figure 3: Evolution of installed DG in Brazil.



Source: ANEEL, 2023b

Figure 4: Hourly load curve - SIN 2019, 2021 (MW)



Source: ONS, 2022

current tariffs, monomial and volumetric, do not segregate these costs (ANEEL, 2019b). For Brazilian Association of Electricity Distributors (ABRADEE), there are no suitable mechanisms that allow better management of the portfolio of contracts held by the utilities (ABRADEE, 2022). Thus, with a reduction in the utility consumer's market, the costs of over-contracting will end up affecting the consumers' tariff in the regulated environment (ABRADEE, 2022). ANEEL recognizes that, the legislation authorizes the transfer of the costs of DG deployment to energy consumers up to the limits established by the electricity sector regulation, the topic still needs to be defined for the Utilities (Freire, 2020). For some utilities, there is still the idea that the contraction of DG has higher costs per MWh when compared to the contraction of energy through centralized auctions promoted by the Federal Government (Freire, 2020).

The DG increasing also raised questions about the current price cap regime and the need to adapt changes in the distribution segment (ANEEL, 2019a). Suggestions arose for a revenue cap model that would be more suitable for distribution. The separation between the components by Distribution System Use and energy into the electricity tariff for the residential user also were suggested (ANEEL, 2019a). Other proposal was about the implementation of multipart tariffs aiming at a mature energy market in the future, reinforcing their immediate application, at least for consumers with DG, through the installation of smart meters (ABRACE, 2019). In this sense, utility EDP-Brazil proposed integrating the TUSD-DG locational concepts for the generation part and a multipart tariff with hourly signaling for the load (ANEEL, 2019b). On the part of the planning body, the proposal suggests a multipart tariff for consumers in the short term, the locational signals in the medium term, and the revision of the regulatory paradigm of the utilities from the decoupling, which would allow the evaluation of the remuneration model based on assets (EPE, 2018; EPE, 2019, p 27).

Recent measures, such as the term extension for requesting access by prosumer to distribution network (LP N°2703/2022) raised the opinions of those involved. LP N°2703 would allow to more participants of the MMDG' Electric Energy Compensation System (SCEE) exemptions of tax nature. To extend the deadline for DG connection represents more income transfer. Thus, the regulated consumer who does not have the own generation system will pay by the subsidy granted to prosumers. On the other hand, the commercial model allows consumers with monthly demand below 500 kW, including low voltage residential ones, to migrate to the Electric Energy Compensation System - SCEE (Medeiros, 2022). However, the sector's current regulations prevent the same consumers from purchasing energy on the Free market. The Ministry of Mines, through Ordinance No. 465/2019 proposes for consumers with an individual load of <500 kW total opening in 2024 (MME, 2019). Additionally, by Ordinance N°690/2022, MME placed in public consultation the propose of all low voltage users participate of ML in 2028 (MME, 2022). Both, DG and ML measures would enter to dispute the subsidies raised by the CDE. There are different positions on this by the groups involved, as identified in Table 3.

5. CASE STUDY FOR A MV NETWORK' USER WITH DISTRIBUTED GENERATION IN THE BRAZILIAN SOUTHEASTERN REGION

The DG expected benefit must-have tools to its monetizing. Thus, to appropriate DERs benefits require the design of specific methodologies. In this work, using measured data from the network and installed DG, and in accordance with the tariff conditions for the A4 subgroup, a discount on the Tariff for Use of the Distribution System - TUSD FIO B component (BRL$/kW) e TUSD energy (BRL$/MWh) and TE (BRL$/MWh) is suggested, linked to the fact that the installed DG would decrease conventional investments for the Utility.

Starting from the NPV of conventional and non-conventional investments or DG investments on MV-network; regulatory conditions from one user of subgroup A4 (2.3 - 25 kV) were assessed. The data correspond to the electricity bills and measurements of circuit USP-105 of the University of São Paulo USP located in the Southeast Brazil region, and Enel-São Paulo utility' customer (Figure 5). Measurements of energy consumption and demand were used for the peak and off-peak periods of this feeder. The measurements of power and energy of the three installed solar-photovoltaic plants in this circuit were also considered: HUPV - Plant; CTPV - ground plant (IEE), and CRPV-ADM roof plant, and the projections for energy and power generation at the biogas plant (still in the process of implementation), as well as the retrofit of lamps inserted as a measure of energy efficiency (recognized as DER), at the University Hospital. The 2019' tariffs correspond to an A4 user, as well as measurements on circuit USP-105 and the installed DG-PV and lamps retrofit of University Hospital (HU). For the calculations, the peak tariffs were applied for DG – energy, and circuit 105, in the period from 12:00 to 15:00, and not in the commercial peak period of 17:30 to 20:30 (Table 3). The power rate – green modality, for this user is the same for peak and off-peak periods. Three options were considered for the complete evaluation of DG insertion. For the utility, the prosumer and other consumers, a cash flow was generated with costs and benefits that allowed the calculation of the Net Present Value (NPV), the Internal Rate of Return (IRR), and Payback. The parameters for the case study are shown in Table 4.

5.1. Utility standpoint

The first part of the assessment corresponds to a conventional investment by the utility on the USP underground network' circuit 105, without DG contribution. The CAPEX was taken according to the information of IPEA (2022), which attributes to urban areas and buried networks, >1,500 kVA/km, a value equivalent to BRL 5 million/km. The circuit 105 maximum demand is ~6 MVA, and length 3.5 km, obtaining a ratio of 1,520 kVA/km ≥1,500 kVA/km. The values can be consulted in Table 4. The CAPEX structure for the underground network basically includes wires, transformers, gas switches, accessories, and civil construction (IPEA, 2022). Civil work is the main factor that it burdens the construction of this network type, which can reach the value of 70% of the investment (IPEA, 2022). As circuit 105 is an already built underground

Table 3: Viewpoints of groups involved: term period for subsidies to prosumers and (ML)' opening measures

Stance group	Law project N°2703/2022 connection period' extension to prosumers	Ordinance MME N°465/2019 Ordinance N°690/GM/MME/2022 Energy Free Market (ML) Opening
National electric energy agency (ANEEL)	Calculates that without Law Project approved, the amount to subsidize around 2.5 million MMDG users will cost USD 1.08 billion in 2023. Comparing with the Social Electric Energy Tariff that benefits 16.5 million consumers (low income) the costs will USD 1.1 billion in 2023.	ANEEL carried out Subsidy Receipt nº 10/2021, proposing 16 questions about Ordinance 465/2019. Among others: implementation of clarification and awareness campaigns for consumers regarding the migration process and action in the ML The Ministry of Mines and Energy opened a new public consultation on Ordinance N°690/2022
ABRACE	New measure will bring an extra cost USD 5 billion to the tariffs of utility consumers until 2045	Proposes create legal measures that mitigate an explosion of subsidies for ML' incentivized sources* on the CDE. The ML opening must not be accompanied by the discount policy at FIO B.
Brazilian association of electricity distributors (ABRADEE)	Consider that since the publication of MMDG regulatory framework, part of the problem has been addressed. However, recognizing the permanence of cross-subsidies caused by MMDG. The problem must be addressed promoting the reduction of subsidies to prosumers with the adoption of a binomial tariff modality.	Warns that without due legal treatment to FM opening to the consumer connected in Low Voltage, the subsidy to ML' incentivized sources* will add costs of USD 16.4 billion to CDE, with up to USD 7.8 billion paid exclusively by the regulated consumer (NPV 2026-2040)
Brazilian association of energy traders (ABRACEEL)	If the proposal to characterize small hydropower plants up to 30 MW is also included as DG, impact on regulated consumers would be up to USD 23.7 billion between 2023-2045.	Explains that the market is already open, but in an unregulated way and with high subsidies, being the opening proposed by the MME a more balanced alternative. The economic benefits of ML' opening are much greater than the impacts of maintaining to incentivized sources* in that market
APINE, ABRACEEL, ABRADE, ABIAPE	There is no economic, social or environmental reason to support the proposal to increase subsidies for a modality that has already prospered, surpassing its own growth projections, thanks to the benefits already granted so far	APINE: It is necessary establish the non-application of discounts on transport tariffs for low voltage consumers who migrate to the (ML) and purchase energy from incentivized sources*. ABRADEE: 2022' Ordinance must be not published, and the (ML) opening occurs based on the legislative measures in progress, respecting the competence, form, and legality according to 2019' ordinance.
Consultants	Subsidies on ML' incentivized sources* represented USD 1.12 billion in 2022, corresponding to 19% of the total subsidies paid by utility consumers. For DG, part of the subsidies is paid by captive consumers and represented USD 280 million out of a total USD 504 million. The other part is intended to cover the loss of the utility's revenue by the FIO B tariff component	Every 10% of residential subgroup migration the ML will represent USD 580 million per year that will be added to CDE expenses. If all high voltage consumers migrate to FM, the impact of the subsidy on the TUSD would change from 4.11% to 6.53%,

Godoi, 2022; Medeiros, 2022; ABRACE, 2022; ABRADEE, 2022; ABRACEEL, 2022; APINE, 2022; ANEEL, 2022a; ANEEL, 2022b; Ribeiro, 2022; Steele, 2022. *Small hydropower plants of 1000 kW- 30,000 kW; developments with installed power up to 1000 kW; solar, wind or biomass sources' injected power into the distribution and/or transmission line up to 30,000 kW

Figure 5: Circuit 105 – university of São Paulo, Brazilian Southeast region

network, from remaining 30%, a partial investment is made for some civil works and equipment on year 0. A partial CAPEX_CM involving the replacement or repair of equipment after it fails was assumed also on year 10 and 20 with values presented in Table 4.

In the city of São Paulo, energy distribution is carried out by 968 km of underground network, 22,503 km of overhead network and 872 km of sub transmission lines (ABRANET, 2018). Maintenance in underground networks is very rare and sporadic (failure in cable or in connection and wear of keys, among others) (ABRANET, 2018). Operation and Maintenance (O and M) costs represent the preventive and/or corrective maintenance actions. Corrective maintenance (CM-CAPEX) was taken from a similar project in Paredes (2022, p.51) and OPEX (operational expenditure) for underground network was considered as BRL 550/km per month (IPEA, 2022). Both, OPEX e CAPEX costs

Table 4: Parameters used for the case study, User A4 with DG

Distributed generation			
University Hospital - HUPV – Enel - 84 kW CTPV – ground plant IEE- 140 kW CRPV – roof plant ADM - 63 KW Biogas Plant Lamps retrofit	-Three solar PV plants: off-peak power: 45.79 kW peak power: 251.34 kW capacity factor: 86% -Biogas: average power: 40kW, maximum power: 75 kW -Retrofit: 140 kW	Total Off-peak power: 221.7 kW Total Peak power: 462.34 kW	PV solar energy: off-peak: 362,630 kWh, peak: 180,966 kWh Biogas energy: Off peak: 237,600 kWh peak: 48,600 kWh
TARIFFS – 2019*			
TUSD green off-peak: 19 USD/MWh Energy-green tariff off-peak: 60 USD/MWh TUSD - green off-peak demand: Without discount: 3.87USD/kW; With discount: 3.24 USD/kW Annual Tariff-Readjustment: 1%		TUSD-green peak: 140.56 USD/MWh Energy-green tariff peak: 101 USD/MWh TUSD-green-peak demand: Without discount: 3.87 USD/kW; With discount: 3.24 USD/kW	
Flag Tariff: USD each 100 kWh/2019		Yellow flag: wet season: USD 0.285	Red flag 1: dry season: USD 0.76
105 circuit			
Off-peak period: 660 h/month		peak period: 60 h/month	
Consumption year	Off-peak: 9,212,258 kWh		peak: 1,412,277 kWh
Demand 2019	Off-peak: 2,709 kW		peak: 5,322 kW
Demand costs	Off-peak: USD 66,463		peak: USD 102,659
Consumption costs	Off-peak: USD 599,240		Peak: USD 260,128
Equipment's Costs (CAPEX)			
DG' installed capacity	Initial Capital USD	O and M costs	Replacement
Biogas plant - 75 kW	$450,000	USD$ 2/op.h	No
HU-PV Enel plant – 84 kW	$105,000	1% of initial investment	panels 11° and 21° year
CPTV – PV ground plant 140 kW	$175,000	1% of initial investment	panels 11°- 21° year
CRPV – PV roof plant 63 kW	$78,750	1% of initial investment	panels 11°-21° year
Inverters	$71,749	20% of initial investment	10 ° year-20° year
Panels	$150,673	42% of initial investment	5%: $5,739
Conventional investments by the utility			
Total investments USD 4,375,000*	Initial partial investment USD 2,187,500*	Replacement investment USD 656,250*	O and M costs per year CM_CAPEX USD 1,378* OPEX USD 4,150*
Utility investments with installed DG by prosumer			
Initial partial investment USD 1,531,250*	Equipment replacement/ repairing. USD 787,500*	O and M costs per year CM_CAPEX USD 1,653* OPEX USD4,980*	
useful life	30 years	Discount rate	10%

Source: ANEEL, 2019c; Diniz, 2017; Montenegro and Ruther, 2020; Irena, 2020; ABRANET, 2018; IPEA, 2022; Paredes, 2022 *dollar/2019: BRL 4/dollar

Table 5: Results case study

Case	NPV USD	IRR	Payback	Criterion
UTILITY: Revenue without discounts and with conventional investments on underground network.	2,791,088	18%	7.6	Complete revenue for the utility and investments of CAPEX, CAPEX_CM, OPEX by the utility.
UTILITY: Revenue with discounts and partial investments by the utility on underground network due to installed DG.	2,864,964	21%	5.8	Partial revenue with discounts to the prosumer for energy and TUSD-energy and TUSD-power components. Partial initial investment by the utility. CAPEX_CM and OPEX increased.
UTILITY: Revenue with discounts and partial investments by the utility on underground network due to installed DG.	2,942,109	20%	5.8	Partial Revenue with discounts to the prosumer for energy and TUSD-energy components. Partial initial investment by the utility. CAPEX_CM and OPEX increased.
PROSUMER: own investments	1,144,851	17%	6.8	The prosumer carried out the total investments in DG and receives a discount for the energy exported and power.

are presented in Table 4. The revenue collected by the distribution company, before taxes, is calculated as 24% according to the tariff composition before taxes of the Periodic Tariff Revision (RTP/2019) by Enel–São Paulo utility. The NPV, IRR and, Payback can be seen in Table 5 and Cash flow in the Appendix.

The second part of the assessment corresponds to DG' investments on the USP-105 circuit by the prosumer with impact on the utility's revenue who in turn within the planning will make minor investments throughout the useful life of the underground network. In this case, prosumer manages DG facilities, and both, the TUSD FIO B component (BRL/kW) and the volumetric components TUSD and energy (BRL/MWh) are discounted of the utility's revenue according to the installed DG. Subsequently, the utility will have a discount proportional to installed DG but only in TUSD and energy volumetric components (Table 4). With installed DG on network, for example, smaller capacity transformers are required, and Initial investment (CAPEX) can be lower (Table 4). On the other hand, O and M costs tend to increase since DG implies to actively manage the networks to modify or adjust all elements and circumstances, sometimes in real time. Thus, O and M costs have been increased 20% compared with the previous case (Table 4). Studies indicate that: "The supply of electrical power through DG presents technical limits due to overvoltage levels" (Chaves, 2009). This fact can increase the value of investments in the network, by the best operation seeking for. Thus, the value of replacement CAPEX_CM was also increased with respect to the previous case (Table 4). The reduced revenues for the utility and in favor of the prosumer were calculated considering the contribution of energy and power of three solar photovoltaic plants, the biogas plant, and the retrofit of the lamps in the University Hospital presented in Table 4. The results of NPV and IRR and, Payback due to discounts of energy and power to the prosumer, and its impact on utility's investment is presented in Table 5. Cash flow can be seen in the Appendix.

5.2. Prosumer Standpoint

It corresponds to a DG investment by the prosumer in the circuit USP-105. The initial CAPEX corresponds to the investments for acquiring the biogas plant and the three solar plants, according to the values shown in Table 4. Solar PV O and M costs, the exchange of inverters, and the replacement of a fraction of the modules are also carried out as indicated by Diniz (2017); Montenegro and Ruther and IRENA (2020) (Table 4). O and M costs for biogas also are indicated in Table 4. The total investment is depreciated over 30 years. In this case, the economic impacts of DG facilities on the prosumer are based on the reduction of the bill value, both by the decrease in energy costs under the Net Metering concept and by the decrease on the charge TUSD FIO B (BRL/kW) of contracted demand and for the decrease in flag costs (Table 4). The avoided costs on peak demand and on peak and off-peak consumption were calculated from the values of energy tariff, TUSD – energy, and TUSD - power Table 4. The results can be seen in the Table 5 and cash flow in the Appendix.

5.3. Other Consumers Standpoint and Planner Role

The first part corresponds to an assessment of the benefits and costs from purchasing DG's energy and power in competition with centralized generation (auction system). Brazilian Decree

Table 6: The impacts on Brazilian Electrical System - SEB[10] due to the purchase of DG by the utility can be transferred to other consumers

Avoided energy cost	Avoided capacity cost	Avoided transmission losses	Avoided distribution losses	Avoided emissions by PV– solar	Avoided emissions by biogas
Criteria used					
Difference between the energy purchased' value in the regulated contracting environment (auctions): BRL 207.34* and the energy generated by DG at the 2019 Marginal Expansion Cost: BRL 187/MWh**. avoided energy by the DG solar-pv and biogás peak and off-peak: 829.7 MWh/year	Reduction of the maximum load of the SIN, calculated as product of: ELCC (52% - 86%), taken 86% according to measurements of already installed DG (peak). Marginal Cost of Power Expansion – 2019: R$688/kW**. 10% of maximum demand on circuit 105: 466.34 kW [Table 3].	*losses (R$)=generated energyGD* Avoided energy cost** $\frac{1}{1-\text{losses}(\%)}-1$ Losses=5%	*losses (R$)=generated energyGD** *Avoided energy cost $\frac{1}{1-\text{losses}(\%)}-1$ Losses=7%	Price per tonne of Carbon: 20 R$/tCO2: price practiced in the CBios market***. Emission Factor SIN 2021 0.5938 t/MWh ****	Price per tonne of Carbon: 20 R$/t$CO_2$: price practiced in the CBios market***. Emission Factor SIN 2021 0.5938 t/MWh ****
NPV avoided values – USD 1,576,146.45					
USD 163,781	USD 1,186,466	USD 79,805	USD 113,233	USD 17,008	USD 15,853
Solar-PV and biogas plants – USD 1,030,000					
NPV: 546,146.45, discount tax: 9% n: 25 years					

Fonte: ANEEL, 2018; *ANEEL, 2019; **EPE, 2020; ***EPE, 2021; ****MCTIC, 2020.

[10]Abbreviation in Portuguese for Sistema Elétrico Brasileiro

5.163/2004 and ANEEL Normative Resolution N°1009/2022 allows the purchase of 10% of the distribution agent's load. The technical-economic parameters of the DG arrangement were considered (Table 4), but also the benefits and costs identified in the Regulatory Impact Analysis report (AIR No. 0004/2018), as follows: (a) avoided energy, (b) increase of National Interconnected System – SIN's capacity considering the effective load-carrying capacity - ELCC of a generator which is defined as the amount by which the system's loads can increase when the generator is added to the system while maintaining the same system reliability (Leisch and Cochran, 2015). (c) reduction in transmission and distribution losses (d) avoided emissions tCO_2/MWh (ANEEL, 2018). The criteria for calculating each benefit and results are shown in Table 6. The impacts on SEB due to the purchase of DG by the distributor can be repassed to other consumers.

The second part brings the monetization of benefits arising from the installed biogas plant at IEE/USP. It involves the exploitation of scope economies resulting from the coupling between the electrical, environmental and production of agricultural inputs sectors. Possible benefits are as follows: Electric: acting as a dispatchable source, during 8,760 hours per year, power factor of 92%, and with energy and power compensation in the period of greatest demand in the USP network (12:00-15:00 h) that is different of commercial peak (17:30 to 20:30). *Treatment of organic waste:* for example, the cost of waste disposal and transportation at USP is between USD 39.41/t and USD 46.9/t. Considering only the allocation of organic waste generated and already correctly segregated in the four restaurants managed by USP for internal energy use – 361.49 tons per year –, it would be possible to reduce – just with the cost of transport and disposal in landfills – almost USD 14,250 per year. Carbon dioxide: avoided by moving fossil sources in the SIN (National Interconnected System) according to MCTIC (2020) and by reducing the amount of organic waste sent to landfills. Regarding the price of carbon, the price practiced in the CBios market in 2020 was taken as a reference according to EPE (2021). It is important to note that this market is currently used to specifically monetize the emissions of companies producing and importing fuels with the purchase and sale of biofuels. Biofertilizers. The digestate produced by the biogas plant in its wet or dry form can be used as a biofertilizer and fulfill a nutrient recycling role for the green areas of the campus, other locations or as an agricultural production input. The value of digestate (without any type of processing) varies from US$ 2.24 to US$ 4.48 per tonne (EGIEYA et al, 2019).

6. CONCLUSION

Pioneers in adopting NEM, such as New York, oriented the measures towards a locational tariff, redeeming the benefits of DERs. Denmark, also a pioneer in the NEM, and Norway with more recent experience have adopted hourly basis to ascertain self-generation guidelines and advanced measurement systems. In Netherlands, where tariff scheme is based on capacity, measures for energy storage are encouraged.

In Brazil, the regulation horizon for DG is less oriented towards exploring the DG benefits and specialization the utilities' functions and more oriented towards the deadlines for a total discount of volumetric tariff components. For capacity component, the long-term allocation of surplus energy (60 months) undervalues the DG-PV load curve, which provides maximum energy and power in the period from 12:00 to 15:00, coinciding with the SIN maximum load, but it is out of step with the commercial peak from 5:30 pm to 8:30 pm. Thus, more efficient measures such as DSM or the use of time-of-use (ToU) tariffs need a better assessment of current conditions.

In countries such as Denmark, Norway, or states as California, the capacity component is less explored but instead there are guidelines on time-off-use tariffs that allow to assess the load curve and energy consumption aligned with DG. In Brazil, the current tariff scheme does not allow possible DG power deductions in the residential tariff subgroup, as its composition is only volumetric. However, in the medium and high voltage subgroups, where the power component is already defined, the contracted demand is that determines the payment of the capacity and does not offer viability for a deduction from the DG installed capacity.

The methodology commonly used in tariff regulation in European Union countries is the revenue cap model, except in Netherlands and Austria, which use the price cap mechanism like in Brazil. Despite being similar mechanisms, the price cap regulatory model blinds increase in utilities' revenue of the which would benefit the consumers. In Brazil, still with a price cap model, initiatives that demand high subsidies are passed on to regulated consumers, among them DERs' increasing.

Recent measures on extending the period of connection to prosumers have led to convergent positions from Utility, Utility Consumers, Large Consumers Traders and Regulator. The coincidences are related to the unnecessary attribution of subsidies to already economically viable sources. Also, by the regulatory framework that will continue to compensate 1:1 the energy exported to the grid until 2045 for old prosumers, and for new ones until 2030.

Subsidies collected from the CDE are disputed by distributed generation, by incentivized sources in the ML, and by the Social Tariff, among other initiatives. ML' opening to low voltage users raised questions about the coexistence of these policies in view of the number of beneficiaries. In 2022, CDE subsidies' 19% were granted to incentivized sources while 4.7% to distributed generation, and 4.8% to Social Tariff.

From the case study it can be inferred that: (a) In the utility's standpoint, continuing with conventional investments on underground network, versus reduction of the investment value, while energy exported by the prosumer is discounted does not represent significant gains. The results were IRR: 18-21%; NPV: USD 2.7- USD 2.8 million and Payback: 7.6-5.8 years. If additional measures for the prosumer are implemented, such as discounts for DG capacity, the gains for utility would be less relevant. An exercise for aerial networks may have different results due to higher O and M costs. (b) From the prosumer's viewpoint, the outlook is favorable, not only due to the results obtained in the case study, but also due to the regulation approved for complete compensation of volumetric tariff components, until 2045, and partial until 2030. (c) To measure the benefits on consumers without DG, there are regulatory tools such as the purchase of energy in competition with the centralized purchase in auctions. However, the utility's perspective on utility consumers' market decreasing and therefore, a revenue' decreasing compromise a long-term vision. (d) Intermittent and dispatchable combination sources in the installed arrangement presented benefits that involve other sectors such as the environmental and agricultural. The regulatory costs of an alternative model including them can be formulated by the planner with a long-term implementation the utilities.

7. RECOMMENDATIONS

A route in the implementation of DERs can be approached considering:

7.1. Methodology for DERs Valuing

To build a methodology or set of procedures that qualify and quantify the benefits and costs of DERs allowing a balance between benefits and costs and their allocation among utilities, prosumers, and consumers without DG. The valuation varies by group involved, but the benefits the DG implementation are similar in several studies. The costs are less evaluated. Costs due to non-compliance with power generation and regulation costs, among others, should also be considered. In the case of Brazil, one of the methodologies may be linked to the DG purchase process. Thus, if the utilities carried out the DG purchase auctions, the benefit/cost could be evaluated in terms of BRL$/ELCC.

7.2. Net Energy Compensation and Measurement Mechanisms

It is necessary to evaluate the Net Metering- rolling credit for 60 months to avoid asymmetry in the allocation of resources and risks. Initially, measures such as a decrease of credits' use period, from 60 to 12 months can be implemented. Later, Pilot programs with accurate metering schemes or net billing (two meters) can be tested to offset benefits such as investment deferral.

7.3. DG Capacity' Assessment and Location Value

The capacity contribution must be evaluated by DG installed type, load requirements, and the expected DG benefits. This would be a start to assigning a locational value to DERs and exploring how much the project decreases network demand or how much the project reduces the need for future utility upgrades. In Brazil, planning updating components in the tariff scheme is relevant, specifically, the separation of wire components (FIO B) in the prosumers' residential billing and the valuation of DG installed capacity in the medium and high voltage subgroups.

7.4. Transition to Capacity Contribution

Demand Response programs can be implemented gradually. Thus, an intermediate measure until the full use of the DG-capacity can be a better exploration of uses by seasonal period and the formulation of time-of-use tariffs targeted. In Brazil, first it is necessary to correct the distortion between the effective peak time of the System (afternoon) and the commercial peak (night) for some consumers, and to induce them to respond to the effective costs of the system.

7.5. Tariff Regulation with Decoupling

Disconnecting utility revenue from energy sales involves changes in the tariff regulation methodology is a process that demands effort and planning. One measure could be the separate purchase of energy and power from distributed generation. In Brazil, the purchase of energy and power in the new distributed generation contracts (DGC) could be included separately to meet the benefits identified in ANEEL NR N°1009/2022.

7.6. DG' Insertion Level

To plan the DG' increasing considering a) the amount of subsidies paid to DG by consumers without DG b) the amount of subsidies to DG compared with the amount for other policies such as Social Tariff and for incentivized sources in the ML, versus number of beneficiaries c) implementation process of the binomial tariff so that the impact of installed power into the network can be compensated/charged.

7.7. Dispatchable Sources and Integration of Energy and Environmental Sectors

The implementation of intermittent sources in complementarity with dispatchable sources, such as biogas, requires interest from the sanitation and electricity sectors. Exploring existing economies of scope in network operation, for example, from biogas generation, would be a strong incentive for network modernization and valuation of distributed resources. The current monetization strategy, which closely links the distributor's revenues to centralized energy flows circulating through the network, needs to be revised to obtain economic and environmental benefits.

7.8. Flexibilization in the Distributor's Functions

To plan the distributor's functions not only linked to the operation and maintenance of the network, but also with participation in the qualification and quantification of the benefits offered by DERs.

8. ACKNOWLEDGMENTS

The authors acknowledge the financial support from the Institute of Energy and Environment of University of São Paulo (IEE-USP), Center for Analysis, Planning and Energy Resources Development (CPLEN), FUSP project number 3827: "From organic waste to bioenergy and biofertilizers: a proposal for innovation in management, regulation and technologies and integration of industrial production chains" as well as from Enel Distribuição São Paulo in partnership with the Brazilian Electricity Regulatory Agency (ANEEL), Priority Energy and Strategic R&D project: "Energy Efficiency and Minigeneration in Public University Institutions", grant number 00390-1086/2018.

REFERENCES

ABRACE. (2019), Brazilian Association of Large Industrial Energy Consumers and Free Consumers. Contribuições Referentes à Consulta Pública Nº 25/2019.

ABRACE. (2022), Contribuições Referente à Consulta Pública Nº 137/2022. Available from: http://antigo.mme.gov.br/c/document_library/get_file?uuid=9a1defdb-b85d-34fc-029d-08c26771e2a2&groupId=36090 [Last accessed on 2023 May].

ABRACEEL. (2022), Contribuição da ARACEEL à Consulta Pública 137/2022 do MME Abertura do Mercado aos Consumidores de Baixa Tensão. Available from: http://antigo.mme.gov.br/c/document_library/get_file?uuid=987f4be0-c68b-0ba5-c1c9-23423db3a373&groupId=36090 [Last accessed on 2023 May].

ABRADEE. (2022), Brazilian Association of Distributors. Contribuição ao Processo de Consulta Pública Nº137/2022/MME Abertura de Mercado Livre Para Consumidores de BT. Available from: https://abradee.org.br/arquivos/contribuicao/20221103%20contribuicao_abradee%20cp%20137-2022-mme_fina_221103_231104.pdf [Last accessed on 2023 May].

ABRANET. (2018), Brazilian Association of Internet. Cost up to 20 Times Higher is the Obstacle to Bury Networks. Available from: https://www.abranet.org.br/Noticias/Custo-ate-20-vezes-maior-e-o-entrave-para-enterrar-redes-1984.html?UserActiveTemplate=site#.ZFkuFHbMLIW [Last accessed on 2023 May].

Aguiar, M., Marinho, M. (2019), Análise dos ciclos de revisões tarifárias periódicas em pernambuco. Revista de Engenharia e Pesquisa Aplicada, 4(1), 15-24.

Alba, J.J., O'Briain, C. (2021), Powering the Energy Transition through Efficient Network Tariffs. Belgium: Union of the Electricity Industry-Eurelectric Aisbl.

ANEEL. (2012), Normative Resolution No. 482, 17 April/2012. Establishes the General Conditions for Access to Microgeneration and Minigeneration Distributed to Electricity Distribution Systems and to the Electrical Energy Compensation System. Brazil: Brazilian Electricity Regulatory Agency.

ANEEL. (2015), Normative Resolution N°687, 24 November/2015. Amends Normative Resolution No. 482, of April 17/2012, and Modules 1 and 3 of the Procedures for Distribution-PRODIST. Brazil: Brazilian Electricity Regulatory Agency.

ANEEL. (2018), Revisão das Regras Aplicáveis à Micro e Minigeração Distribuída-Resolução Normativa Nº 482/2012. Relatório de Análise de Impacto Regulatório Nº 0004/2018-SRD/SCG/SMA/ANEEL. Brazil: Brazilian Electricity Regulatory Agency.

ANEEL. (2018a), Tarifa Binômia: Modelo Tarifário do Grupo B. Relatório de Análise de Impacto Regulatório nº 02/2018-SGT/SRM/ANEEL. Brasília, 12/12/2018-Versão nº 1. Brazil: Brazilian Electricity Regulatory Agency.

ANEEL. (2019), Revisão Tarifária Periódica. 5ª Revisão Tarifária Periódica ENEL São Paulo. RTP 2019. Brazil: Brazilian Electricity Regulatory Agency.

ANEEL. (2019a), Nota Técnica nº 27/SRM/SGT/SPE/SRD-2019/ANEEL. Brazil: Brazilian Electricity Regulatory Agency.

ANEEL. (2019b), Anexo 1 da Nota Técnica n° 0078/2019-SRD/ANEEL, de 7/10/2019. Análise das Contribuições-AP n° 01/2019. Brazil: Brazilian Electricity Regulatory Agency.

ANEEL. (2019c), Resolução Homologatória N°2568, 2 July/2019. Homologa o Resultado da Quinta Revisão Tarifária Periódica-RTP, e dá Outras Providências. Brazil: Brazilian Electricity Regulatory Agency.

ANEEL. (2022), ANEEL Nº 1009 de 22/03/2022. CAPÍTULO IV das Condições Para a Comercialização de Energia Elétrica Proveniente da Geração Distribuída. Brazil: Brazilian Electricity Regulatory Agency.

ANEEL. (2022a), Consumers Will Pay Up to R$ 125 Billion in Energy Tariffs with the Expansion of the List of Beneficiaries and the Postponement of Gratuity for Another 6 Months. Available from: https://www.gov.br/aneel/pt-br/assuntos/noticias/2022/consumidores-pagarao-ate-r-125-bilhoes-nas-tarifas-de-energia-com-a-ampliacao-do-rol-de-beneficiarios-e-a-postergacao-em-mais-6-meses-da-gratuidade-para-uso-da-rede-de-distribuicao-pelas-instalacoes-de-geracao-distribuida [Last accessed on 2022 Dec].

ANEEL. (2022b), ANEEL Studies Regulatory Measures to Allow the Opening of the Free Market for Consumers with a Load of Less Than 500 kW. Available from: https://www.gov.br/aneel/pt-br/assuntos/noticias/2022/aneel-estuda-medidas-regulatorias-para-permitir-a-abertura-do-mercado-livre-para-consumidores-com-carga-inferior-a-500-kw-1 [Last accessed on 2023 May].

ANEEL. (2023), ANEEL Define Regras Para o Custeio da Geração Distribuída por Meio da CDE e Dos Processos Tarifários. Available from: https://www.gov.br/aneel/pt-br/assuntos/noticias/2023/aneel-define-regras-para-o-custeio-da-geracao-distribuida-por-meio-da-cde-e-dos-processos-tarifarios [Last accessed on 2023 Mar].

ANEEL. (2023a), Resolução Homologatória N°3175 de 07 de Março de 2023. Brazil: Brazilian Electricity Regulatory Agency.

ANEEL. (2023b), ANEEL Regulamenta Marco Legal da Micro e Minigeração Distribuída. Available from: https://www.gov.br/aneel/pt-br/assuntos/noticias/2023/aneel-regulamenta-marco-legal-da-micro-e-minigeracao-distribuida [Last accessed on 2023 Mar].

Ansarin, M., Ghiassi-Farrokhfal, Y., Ketter, W., Collinsc, J. (2020), The economic consequences of electricity tariff design in a renewable energy era. Applied Energy, 275, 115317.

APINE. (2022), Contribuições da Apine Para a Consulta Pública nº 137/2022 Available from: http://antigo.mme.gov.br/c/document_library/get_file?uuid=a2c63717-7132-100b-b137-790c124bb446&groupId=36090 [Last accessed on 2023 May].

ARERA. (2018), Regulatory Authority for Energy and Environment. Capacity-Based Network Tariffs for Italian Electricity Household. Network Tariffs Workshop. Brussels, 19th October 2018. Available from: https://www.ceer.eu/documents/104400/-/-/c2310057-9124-4708-8f56-6a587f76f569 [Last accessed on 2022 Nov].

Brazil. (2004), Decree 5163, July 30, 2004. Regulates the Commercialization of Electric Energy, the Process of Granting Concessions and Authorizations for the Generation of Electric Energy, and Other Measures.

Brazil. (2022), Law Nº 14.300, January 6, 2022. Establishes the Legal Framework for Microgeneration and Distributed Minigeneration, the Electric Energy Compensation System (SCEE) and the Social Renewable Energy Program (PERS).

Câmara, L. (2020), Sistemas Energéticos Distribuídos. Curso: Introdução aos Recursos Energéticos Distribuídos: Conceitos e aplicações. Grupo de Estudos do Setor Elétrico.

Campbell, A (2015), Cap Prices or Cap Revenues? The Implications of Alternative Electricity Pricing Schemes in Jamaica. In: Energy Security, Technology and Sustainability Challenges across the Globe, Antalya, Turkey-25-27, 2015, 38th IAEE International Conference.

Campos, I., Pontes, G., Marín-González, E., Gährs, S., Hall, S., Holstenkamp, L. (2020), Regulatory challenges and opportunities for collective renewable energy prosumers in the EU. Energy Policy, 138, 111212.

Canal Energia. (2022), Free Market Grows and Reaches 38% of the Electricity Consumed in Brazil. Available from: https://www.canalenergia.com.br [Last accessed on 2023 May].

Castañeda, M., Jiménez, M., Zapata, S., Franco, C., Dyner, I. (2017), Myths and facts of the utility death spiral. Energy Policy, 110, 105-116.

Castro, N., Chaves, A., Ferreira, D., Tommaso, F., Ozorio L., Maestrini, M., Miranda, M., Brandão, R., Mendes, P. (2020), Análise Das Propostas de Alterações Metodológica, Para Determinação das Metas Regulatórias das Perdas Não Técnicas, na Distribuição de Energia Elétrica. Texto de Discussão do Setor Elétrico Nº 94, Rio de Janeiro.

CFE. (2022), Comisión Federal de Electricidad. Tarifa DAC, Noviembre de 2022. Available from: https://app.cfe.mx/aplicaciones/ccfe/tarifas/

tarifas/tarifas_negocio.asp?tarifa=2 [Last accessed on 2022 Nov].

CGE. (2022) Compañía General de Electricidad. Tarifas. Available from: https://www.cge.cl/informacion-comercial/tarifas-y-procesos-tarifarios [Last accessed on 2022 Nov].

Chaves, F.D.M. (2009), Serviços Ancilares Através da Geração Distribuída: Reserva de Potência Ativa e Suporte de Reativos. Tese de Doutorado. Programa de Planejamento Energético. Faculdade de Engenharia Mecânica. Universidade Estadual de Campinas.

CNPE. (2020) National Energy Policy Council. Resolution N°15, 9 December 2020 Establishes National Guidelines for Public Policies aimed at Distributed Microgeneration and Minigeneration in the Country.

Codeiro, I. (2019), Proposta de Revisão da Geração Distribuída: A Quem Interessa? Available from: https://inergial.com.br/proposta-de-revisao-da-geracao-distribuida-a-quem-interessa [Last accessed on 2020 Sep].

Comello, S., Reichelstein, S. (2017), Cost competitiveness of residential solar PV: The impact of net metering restrictions. Renewable and Sustainable Energy Reviews, 75, 46-57.

Diniz, J. (2017), Metodologia Para Análise de Investimento em Sistemas Fotovoltaicos Considerando Parâmetros de Incerteza e Métricas de Risco. Programa de Pós-Graduação em Engenharia Elétrica. Brazil: Universidade Federal de Minas Gerais, Escola de Engenharia.

Dubash. (2004), Electric Power Reform: Social and Environmental Issues. Encyclopedia of Energy. Available from: https://www.sciencedirect.com/topics/engineering/revenue-cap [Last accessed on 2023 Jan].

Egieya, J., Cucek, L., Zirngast, K., Isafiade, A., Pahor, B., Kravanja, Z. (2019), Synthesis of biogas supply networks using various biomass and manure types, 2018. Computers and Chemical Engineering, 122, 129-151.

Energyhub. (2021), Electricity Prices in Canada 2021. Available from: https://www.energyhub.org/electricity-prices [Last accessed on 2022 Nov].

ENSEK. (2021), New Capacity Based Distribution Tariffs in Flanders, Belgium. Available from: https://ensek.com/news/ensek-regulation-update [Last accessed on 2022 Nov].

EPE. (2018), Brazilian Energy Research Agency. Distributed Energy Resources: Impacts on Energy Planning Studies. Discussion Paper.

EPE. (2019), Recursos Energéticos Distribuídos. Documento de Apoio ao PNE 2050. Janeiro de 2019. Rio de Janeiro, Brazil: Brazilian Energy Research Agency.

EPE. (2020), Custo Marginal de Expansão do Setor Elétrico Brasileiro Metodologia e Cálculo-2020. Brazil: Brazilian Energy Research Agency.

EPE. (2021), Análise de Conjuntura dos Biocombustíveis-Ano 2020. Julho de 2021, Nota Técnica. Brazil: Brazilian Energy Research Agency.

EPE. (2022), Brazilian Energy Research Agency. Leilões: Leilões de Energia Leilões. Available from: https://www.epe.gov.br [Last accessed on 2022 Dec].

EPE. (2023), Data on Distributed Generation. Brazil: Brazilian Energy Research Agency. Available from: http://shinyepe.brazilsouth.cloudapp.azure.com:3838/pdgd [Last accessed on 2023 Jan].

ERSE. (2022), Entidade Reguladora dos Serviços Energéticos-Tarifas e Preços Para a Energia Elétrica e Outros Serviços em 2022, e o Período de Regulação 2022-2025. Available from: https://www.erse.pt/media/ljchh3mi/tarifas-e-pre%C3%A7os-2022.pdf [Last accessed on 2022 Nov].

Faruqui, A., Hledik, R., Sergici, S. (2019), A Survey of Residential Time-of-Use (TOU) Rates. Available from: https://www.brattle.com/wp-content/uploads/2021/05/17904_a_survey_of_residential_time-of-use_tou_rates.pdf [Last accessed on 2022 Nov].

Fine, P., De Martini, P., Succar, S., Robison, M. (2015), The Value in Distributed Energy: It's All about Location. Available from: http://www.ourenergypolicy.org/wp-content/uploads/2015/09/value_in_distributed_energy_location.pdf [Last accessed on 2020 Feb].

Freire, W. (2020), Aneel vê Espaço Para Contratação de GD Visando a Melhoria No Fornecimento. Available from: https://canalenergia.com.br/noticias/53152395/aneel-ve-espaco-para-contratacao-de-gd-visando-a-melhoria-no-fornecimento [Last accessed on 2020 Sep].

Gautier, A., Jacqmin, J., Poudou, J.C. (2017), The Prosumers and the Grid. CESifo Working Paper Series 6814, CESifo.

Geffert, W., Strunk, K. (2017), Beyond net metering: A model for pricing services provided by and to distributed generation owners. The Electricity Journal, 30(3), 36-43.

Godoi. (2022), Entidades Do Setor Elétrico Divulgam Carta Contra o PL 2703. Available from: https://www.canalenergia.com.br/noticias/53232401/entidades-do-setor-eletrico-divulgam-carta-contra-o-pl-2703

Hall, J., Kallay, J., Napoleon, A., Takahashi, K., Whited, M. (2018), Locational and Temporal Values of Energy Efficiency and Other DERs to Transmission and Distribution Systems. Synapse. United States: Energy Economics, Inc. Available from: http://www.synapse-energy.com/sites/default/files/aceee-paper-values-ee-der.pdf [Last accessed on 2020 Sep].

Hinz, F., Schmidt, M., Möst, D. (2018), Regional distribution effects of different electricity network tariff designs with a distributed generation structure: The case of Germany. Energy Policy, 113, 97-111.

Hydroquebec. (2022), Comparison of Electricity Prices in Major North American Cities. Canada: Hydroquebec. Available from: https://www.hydroquebec.com/data/documents-donnees/pdf/comparison-electricity-prices.pdf [Last accessed on 2022 Nov].

IEA. (2022), Unlocking the Potential of Distributed Energy Resources Power System Opportunities and Best Practices. France: International Energy Agency.

IPEA. (2022), Análise Sobre o Enterramento de Infraestrutura de Redes Dos Setores de Distribuição de Energia e Telecomunicações. Texto de Discussão 2727. Rio de Janeiro, Brazil: Institute of Applied Economic Research.

IREC. (2014), A Regulator's Guidebook: Calculating the Benefits and Costs of Distributed Solar Generation. United States: Interstate Renewable Energy Council.

IRENA. (2019), Innovation Landscape Brief: Market Integration of Distributed Energy Resources. Abu Dhabi: International Renewable Energy Agency.

IRENA. (2020), Renewable Power Generation Costs in 2019. Abu Dhabi: International Renewable Energy Agency.

Leisch, J., Cochran J. (2015), Using Wind and Solar to Reliably Meet Electricity Demand. USAID Office of Global Climate Change. USA: National Renewable Energy Laboratory. Available from: https://www.nrel.gov/docs/fy15osti/63038.pdf [Last accessed on 2023 Mar].

Linvill, C., Shenot, J., Lazar, J. (2013), Designing' Distributed Generation Tariffs Well: Fair Compensation in a Time of Transition. Montpelier, Vermont: Rap Energy Solutions.

Lu, L., Waddams, C. (2018), Designing Distribution Network Tariffs that are Fair for Different Consumer Groups. United Kingdom: Centre for Competition Policy, University of East Anglia.

Martín, H., de la Hoz, J., Arnau, A., Coronas, S., Matas, J. (2021), Analysis of the net metering schemes for PV self-consumption in Denmark. Energies, 14, 1990.

McAlister, R., Manning, D., Bird, L., Coddington, M., Volpi, C. (2019), New Approaches to Distributed PV Interconnection: Implementation Considerations for Addressing Emerging Issues. United States: NREL. Available from: https://www.nrel.gov/docs/fy19osti/72038.pdf [Last accessed on 2020 Sep].

MCTIC. (2020), Ministry of Science, Technology and Innovations.

Emissions Factor. Available from: https://antigo.mctic.gov.br/mctic/opencms/ciencia/SEPED/clima/textogeral/emissao_despacho.html [Last accessed on 2021 Dec].

Medeiros, R. (2022), Mercado Livre é Saída Para Guerra de Fornecedores de Energia. Available from: https://www.poder360.com.br/opiniao/mercado-livre-e-saida-para-guerra-de-fornecedores-de-energia [Last accessed on 2023 Mar].

MME. (2019), Ministry of Mines and Energy. Ordinance N°465 of 12 December/2019.

MME. (2022), Ministry of Mines and Energy. Ordinance N°690/GM/MME of 29 September/2022.

Montenegro, A., Rüther, R. (2020), Método de Cálculo de Retorno de Investimento em Geração Distribuída Fotovoltaica Considerando os Fluxos de Caixa e Créditos de Energia Mensais. In: VIII Congresso Brasileiro de Energia Solar-Fortaleza, 01 a 05 de junho de 2020.

NCSL. (2017), National Conference of State Legislatures. State Net Metering Policies. Available from: https://www.ncsl.org/research/energy/net-metering-policy-overview-and-state-legislative-updates.aspx [Last accessed on 2022 Nov].

NYPA. (2017), Available from: https://www.nypa.gov/-/media/nypa/documents/document-library/operations/recharge-ny/rny-schedule-of-rates.pdf [Last accessed on 2022 Nov].

OCU. (2021), Spanish Consumers Organization. Available from: https://www.ocu.org/vivienda-y-energia/gas-luz/informe/nuevas-tarifas-acceso [Last accessed on 2022 Nov].

Oliveira, C.C.B. (2018), Modernização das Tarifas e Medição de Energia. 11° Forum Latinoamericano de Smart Grid. 17-18 de Setembro de 2018. São Paulo-SP.

ONS. (2022), Hourly Load Curve. Operador Nacional do Sistema. Available from: https://www.ons.org.br/Paginas/resultados-da-operacao/historico-da-operacao/curva_carga_horaria.aspx [Last accessed on 2021 Oct].

Paredes, A.B.L. (2022), The Decision on Overhead or Underground Power Cables: An Economic Analysis of E-REDES Investment Projects. Dissertation Master. Portugal: Universidade do Porto.

Picciariello, A., Ramirez, C.R.V., Guillén, J., Reneses, J., Marin, P.F., Söder, L. (2014), Distribution Network Tariffs and Distributed Generation: Need for an Innovative Methodology to Face New Challenges. Available from: https://www.iaee.org/en/publications/proceedingsabstractpdf.aspx?id=7870 [Last accessed on 2020 Oct].

Picciariello, A., Reneses, J., Söder, L. (2015), Distributed generation and distribution pricing: Why do we need new tariff design methodologies? Electric Power Systems Research, 119, 370-376.

Pudjianto, D., Cao, D.M., Grenard, S., Strbac, G. (2006), Method for Monetarisation of Costs and Benefits of DG Options. Europe: Intelligent Energy Europe (EIE).

RAP. (2016), Revenue Regulation and Decoupling: A Guide to Theory and Application. 2nd Printing. Montpelier, Vermont: RAP.

REN21. (2022), Renewables 2022 Global Status Report. REN21 Secretariat c/o UN Environment Programme. Paris, France: REN21.

Ribeiro. (2022), The Rhetoric of Distributed Generation Subsidies and PL 2703. Available from: https://energiahoje.editorabrasilenergia.com.br/a-retorica-dos-subsidios-da-geracao-distribuida-e-o-pl-2703 [Last accessed on 2023 May].

SCE. (2022), Southern California Edison. Time-Of-Use Residential Rate Plans. Available from: https://www.sce.com/residential/rates/time-of-use-residential-rate-plans [Last accessed on 2022 Nov].

Simone, L.F.C., Borges, G.G. (2019), Mudança do Regime Tarifário do Preço-teto Para Receita-teto Para as Distribuidoras de Energia Elétrica. XXV SNPTEE Seminário Nacional de Produção e Transmissão de Energia Elétrica, 10-13 de Novembro de 2019, Belo Horizonte-MG.

Sioshansi, R. (2016), Retail electricity tariff and mechanism design to incentivize distributed renewable generation. Energy Policy, 95, 498-508.

Steele, P. (2022), Possible Effects of Free Market Expansion on Energy Tariffs. Available from: https://www.trsolucoes.com/conteudo/articles/impacto_da_expansao_do_mercado_livre_nas_tarifas_de_energia [Last accessed on 2023 May].

SWECO. (2019), SWECO Oslo Economics. Distributed Energy Production and Self-consumption in the Nordics: A report to Nordic Energy Research. Norway: SWECO.

UTE. (2022), The National Administration of Power Plants and Electrical Transmissions. Available from: https://portal.ute.com.uy/sites/default/files/docs/pliego%20tarifario%20vigente%20desde%201%20de%20enero%20de%202022.pdf [Last accessed on 2022 Nov].

APPENDIX

Utility's standpoint: Cash flow without DG and conventional investments on circuit 105 of the USP' underground network

year	Energy revenue circuit 105 USD	Power revenue circuit 105 USD	Flag revenue USD	Distribution portion pre-tax USD	O and M costs network USD	Capex USD −2,187,000	EBIT USD −2,187,000
1	1,139,236.82	134,740.26	70,287.72	322,623.55	5,528		317,096
10	1,491,356	176,386.25	76,874.55	418,708	7,236.61	−656,250	− 244,779
11	1,575,462.34	186,333.69	77,643.29	441,465.44	7,644.73		433,821
20	3,230,880.67	382,124	84,917.33	887,501.27	15,677.43	−656,250	215,574
21	3,587,634.69	424,318	85,766.50	983,452.64	17,408.54		966,044
30	15,315,535.50	1,811,405	95,687	4,133,430.59	74,316.66		4,059,114

Utility's standpoint: Cash flow - decreased revenue for utility by installed DG by the prosumer on circuit 105 of the USP' underground network

year	Energy revenue with discount by NEM (USD)	Power revenue without discount by installed capacity (USD)	Flag revenue discount 10% (USD)	Distribution portion pre-tax (USD)	O and M costs network (USD)	CAPEX (USD)	EBIT (USD)
0						-1,531,250	-1,531,250
1	1,012,566	134,740.26	56,933	289,017.41	6,637		282,380
10	1,325,533	176,386.25	60,906	375,078.12	7,222.85	-787,500	-419,645
11	1,400,288	186,333.69	61,131	395,460.56	7,295		388,165
20	2,871,641	382,124	58,485.33	794,940.17	7,978.52	- 787,500	-538
21	3,188,728	424,318	57,268.62	880,875.59	8,058.31		872,817
30	13,612,612	1,811,405	1,075	3,702,022.15	8,990.40		3,693,032

Prosumer viewpoint: cash flow with DG installed- circuit 105

year	Avoided enregy costs	Avoided power costs	Avoided flag costs	O and M costs solar PV and biogas	Depreciation	CAPEX	EBIT
0						−921,791	−921,791
1	126,671	17,975.84	7,028.8	20,868	14,350		116,458
10	165,822.79	23,531.88	9,201.2	27,317	14,350	−71,750	85,138.62
11	175,174.50	24,858.98	9,720.2	28,858	14,350	−7,534	159,012
12	185,978.88	26,392.23	10,319.7	30,638	14,350		177,703
20	359,239.25	50,979.57	19,933.6	59,180	14,350	−71,750	284,872.13
21	398,906.47	56,608.74	22,134.7	65,715	14,350	−7,534	390,051.14
22	445,168.51	63,173.78	24,701.7	73,336	14,350		445,357.87
30	1,702,923.15	241,661.5	94,492.6	280,536	14,350		1,744,191.22